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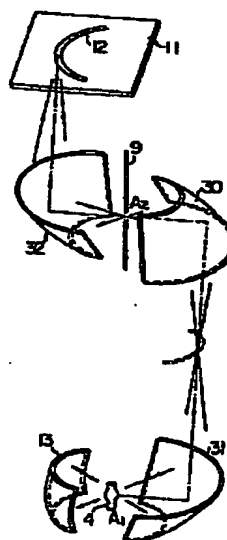
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⑥4 Reflection type optical focusing apparatus.

⑥7 A reflection-type optical focusing apparatus comprising an optical focusing system including at least two 4th-degree surface reflectors (30, 31) with their revolving symmetric axis formed by a line connecting the position of a point source (A1) and the point source focusing position (A2), said reflectors being used in combination so that the light emitted from a point source placed at the point source position is focused to form a virtual point source at the point source focusing position, and a 4th-degree surface reflector (32) with its cross-section, on a plane including the revolving symmetric axis, forming a part of an ellipse with its major axis having a certain inclination with respect to the revolving symmetric axis, said virtual point source being located at one focal point (A2) of the ellipse so that a light image in the shape of an arc band (12) is obtained.

FIG. 13



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## REFLECTION TYPE OPTICAL FOCUSING APPARATUS

1           The present invention relates to a reflection-type optical focusing apparatus which provides a light source in the shape of an arc band used in a full-size reflection-type exposing apparatus and the like.

5           The extra pressure mercury lamp and xenon-mercury lamp used as a point source for exposing apparatus in semiconductor fabrication are shaped as shown in Fig. 1, where reference number 1 denotes a cathode electrode and 2 denotes an anode electrode. Lamps of this type emit  
10 light by discharging, resulting in a somewhat planar light source rather than an ideal point source. Therefore, this light source is once focused at some position, then reduced to an ideal point source using a pinhole filter and the like.

15           Use of transmitting components such as lens for focusing a point source is undesirable for some wavelength, since it causes absorption and aberration. On the other hand, use of reflectors for focusing a light beam is free from these problems.

20           One of focusing methods using reflectors is the use of an ellipsoidal reflector. In this case, the highest light distribution intensity of the lamp appears in the perpendicular direction with respect to the main axis of the lamp, and in order to obtain the largest  
25 effective energy at the focal point, the reflector has

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1 to be shaped as shown in Fig. 2. In Fig. 2, reference  
number 3 shows the conventional ellipsoidal reflector,  
4 is a lamp, 5 is the position of the point source, and  
6 is the point source focusing position. However, the  
5 conventional ellipsoidal reflector 3, when provided with  
a larger radiation angle around the main axis, does not  
present a uniform light distribution around the focal  
point.

There is known an apparatus similar to the  
10 present invention, as disclosed in Japanese Patent Laid-  
open No. 54-123876 (corresponding to U.S. Patent No.  
4,294,538) However, this apparatus causes the failure  
of focusing in the meridian direction on the focal point  
due to coma aberration, resulting in a large energy  
15 loss when a pinhole filter is used.

It is therefore an object of the present inven-  
tion to solve the foregoing prior art deficiencies and  
provide an optical focusing apparatus for obtaining a  
light source in the shape of an arc band having a  
20 uniform light distribution characteristic.

The present invention is also characterized  
in that there are provided reflectors each shaped in a  
fourth-degree surface whose cross-section forms a  
part of an ellipse with its major axis having a certain  
25 inclination with respect to the revolving symmetric  
axis, on one focal point of the ellipse is located the  
effective point light source, thereby obtaining an arc  
band light source to be used in an illuminating apparatus

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1 for a full-size reflection-type exposing apparatus having  
a high resolution and short exposing time.

The present invention is characterized in that  
there is provided the combination of at least two  
5 reflectors each shaped in a fourth-degree surface having  
a revolving symmetric axis formed by a line connecting  
the position of the point source and the position of the  
point source focal point, so that the effective point  
light source as described in the above paragraph, is  
10 obtained.

According to the present invention, a light  
source of a short wave length (deep UV) ranging 200-300 nm  
can be obtained by use of an Xe-Hg lamp which provides  
a point source, and a high resolution is achieved.  
15 Moreover, since optical transmitting components are  
not used, no optical loss occurs, and a light beam can be  
projected within a narrow band effectively.

The present invention will be apparent from  
the following detailed description taken in conjunction  
20 with the accompanying drawings, in which:

Figure 1 shows an external view of the lamp used  
as a point source;

Figure 2A is a perspective view showing the  
optical focusing system for a point source using the  
25 conventional ellipsoidal reflector;

Figure 2B is a side view of the optical system  
shown in Fig. 2A;

Figure 3 is an illustration showing the present

1 invention;

Figure 4A is an illustration showing an embodiment of the present invention;

Figure 4B is a cross-sectional view of the  
5 arrangement shown in Fig. 4A;

Figure 5A is an illustration showing the arrangement of another embodiment of the present invention;

Figure 5B is a cross-sectional view of the arrangement shown in Fig. 5A;

10 Figure 6A is an illustration showing the arrangement of another embodiment of the present invention;

Figure 6B is a cross-sectional view of the arrangement shown in Fig. 6A;

15 Figure 7A is an illustration showing the portions of  $dz$ ,  $\theta$  and  $dy$  shown in Figs. 6A and 6B;

Figure 7B is a graphical representation showing the focusing characteristics when the center of curvature is displaced from the revolving symmetric axis;

20 Figures 8A - 8E are ray tracing diagrams;

Figure 9 is an illustration showing still another embodiment of the present invention;

Figure 10 is a ray diagram for the light emitted from the finite light source used for the arc  
25 band illumination, showing the effect of the present invention;

Figure 11A is an illumination ray diagram based on the system of the present invention;

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1            Figures 11B and 11C are illumination ray  
diagrams based on the conventional system;

            Figure 12 is an illustration showing the optical  
system of the full-size reflection-type exposing apparatus  
5    embodying the present invention;

            Figure 13 is an illustration exemplifying a  
means for obtaining an effective point source according  
to the present invention;

            Figure 14 is a ray tracing diagram for the  
10    arc band illumination light produced by the combination  
of three 4th-degree surfaces each having an ellipsoidal  
cross-section as shown in Fig. 13;

            Figure 15 is an illustration explaining the  
shape of the two concave mirrors used in the embodiment  
15    of Fig. 13;

            Figure 16 is a ray tracing diagram for the arc  
band illumination light produced by the combined illumi-  
nation system made up of two 4th-degree surfaces each  
having a circular cross-section shown in Fig. 13 and  
20    a 4th-degree surface having an ellipsoidal cross-section  
shown in Fig. 15; and

            Figure 17 is an illustration showing an embodi-  
ment of the full-size reflection-type exposing apparatus  
with the present invention applied thereto.

25            The present invention will now be described  
in detail by way of illustrated embodiments.

            When focusing a point source in order to use  
the lamp energy most effectively, the light beam

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- 1 perpendicular to the lamp, where it has the highest  
light distribution intensity, should be used. In addition,  
in order to obtain the uniform light distribution  
around the focal point, the most suitable optical system  
5 is the arrangement of 4th-degree surface reflectors  
having a revolving symmetric axis formed by a line  
connecting the point source position and the point source  
focal position, with the highest luminance portion of  
the lamp being placed at the point source position.
- 10 Fourth-degree surface reflectors are classified by the  
shape of the cross-section which is cut on the plane  
including the revolving symmetric axis. For example,  
assuming two 4th-degree surface reflectors each having  
an ellipsoidal cross-section with one focal point located  
15 out of the revolving symmetric axis and focal point  
located at the point source position and the point source  
focal point, respectively, a light beam originated from  
point A1 reflects on surface S1 and focuses at C1 in  
the shape of arc, then further reflects on surface S2  
20 and focuses at point A2, as shown in Figs. 4A and 4B.

In another example, if reflectors have an  
ellipsoidal and hyperbolic cross-sections each having  
one focal point located out of the revolving symmetric  
axis and another focal point located at the point source  
25 position and the point source focal position, respectively,  
a light beam originated from point A1 focuses at point  
A2 as shown in Figs. 5A and 5B. Reflectors having circular  
cross-sections generally cause the coma aberration.

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1 Figure 7B shows intersections of the principal ray and  
 a ray having an inclination of  $\theta$  with respect to the  
 principal ray measured by displacing the center of the  
 curvature of the circle from the revolving symmetric  
 5 axis as shown in Fig. 7A. In Fig. 7B, if  $dz$  is  
 equal to zero (as disclosed in Japanese Patent Laid-  
 open No. 54-123876 and corresponding U.S. Patent No.  
 4,294,538) or if  $dz$  is negative,  $\theta$ - $dy$  becomes a curve  
 and the coma aberration is not eliminated. On the other  
 10 hand, if  $dz$  increases in positive,  $\theta$ - $dy$  becomes a  
 straight line, and when two 4-th-degree surface reflectors  
 are combined with the focal point C being set temporarily  
 to the position of  $dy$  with  $\theta=0$  as shown in Figs. 6A  
 and 6B, the aberrations of both reflectors cancel  
 15 each other, resulting in a production of a clear image.  
 Thus the present invention allows the production of a  
 clear point source image by using the light source  
 energy most effectively.

Next, the reflection-type optical focusing  
 20 system embodying the present invention will be described  
 with reference to Figs. 4A and 4B. Surfaces S1 and S2  
 define concave mirrors 20 and 21 on a 4th-degree  
 surface obtained by rotating the ellipsoidal cross-  
 sections expressed by equation (1) on a plane including  
 25 their revolving symmetric axis 7.

$$\text{Ellipse: } \overline{A_1 P_i} + \overline{P_i C} = r_1 + h = \text{const } (i=1, 2) \dots (1)$$



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1            Since points A1, C and A2 are the focal points  
of these ellipses, the light source located at point A1  
focuses to form an arc at point C, then it focuses to  
form a point at point A2. Figure 8A shows the project-  
5 ing ray at point A1, and Fig. 8B (ellipsoidal cross-  
section plus ellipsoidal cross-section) shows the  
incident ray at point A2. It can be seen clearly that  
they have better characteristics as compared with  
Fig. 8D (circular cross-section (with center on the axis)  
10 plus circular cross-section (with center on the axis))  
which results from the prior art arrangement disclosed in  
Japaense Patent Laid-open No. 54-123876.

Next, another embodiment of the reflection-  
type optical focusing system according to the present  
15 invention will be described with reference to Figs. 5A  
and 5B. Surfaces S1 and S2 define concave mirrors 22  
and 23 on 4th-degree surfaces obtained by rotating the  
ellipsoidal and hyperbolic cross-sections expressed by  
equations (2) and (3), respectively, on a plane including  
20 their revolving symmetric axis. 7.

$$\text{Ellipse: } \overline{A_1P_1} + \overline{P_1C} = h + \ell_1 = \text{const} \dots\dots (2)$$

$$\text{Hyperbola: } \overline{A_2P_2} - \overline{P_2C} = h - \ell_2 = \text{const} \dots\dots (3)$$

Since points A1 and C are the focal points of  
the ellipse and points A2 and C are the focal points  
of the hyperbola, the light source at point A1 forms

1 an arc-shaped virtual image at point C, then the image  
 focuses at point A2 to form a point. The incident ray as  
 shown in Fig. 8C (ellipsoidal cross-section plus  
 hyperbolic cross-section) is obtained at point A2 for  
 5 the projecting ray shown in Fig. 8A. It can be seen  
 clearly that they have better characteristics as compared  
 with Fig. 8D which results from the prior art arrangement  
 disclosed in the above-mentioned Japanese Patent Laid-  
 open No. 54-123876.

10 Next, still another embodiment of the reflec-  
 tion-type optical focusing system according to the present  
 invention will be described with reference to Figs. 6A  
 and 6B. Surfaces S1 and S2 define concave mirrors 24 and  
 25 on 4th-degree surfaces obtained by rotating the  
 15 circular cross-sections expressed by equation (4) on  
 a plane including their revolving symmetric axis 7.

$$(\overline{A_i P_i} - h)^2 + (\overline{P_i C_i} - l_i)^2 = r^2 = \text{cont} (i=1, 2) \dots (4)$$

where  $h > 0$ .

The light source located at point A1 forms an  
 arc at point C, then it focuses at point A2 to form  
 20 substantially a point. For example, in the case of the  
 prior art arrangement disclosed in the Patent Laid-open  
 No. 54-123876 with dimensions given as  $h = 11 - 0.0 \text{ mm}$   
 and  $r = 150 \text{ mm}$ , the projecting ray as shown in Fig. 8A  
 results in an incident ray at point A2 as shown in Fig.  
 25 8D, whereas, according to the present invention, when

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1 the centers of the circles are located out of the  
revolving symmetric axis with the dimensions being given,  
for example, as  $l_1 = l_2 = 040.6$  mm,  $h = 75.1$  mm and  
 $\gamma = 250.0$  mm, the incident ray is improved as shown in  
5 Fig. 8E (circular cross-section (with center out of the  
axis) plus circular cross-section (with center out of  
the axis)).

The foregoing embodiments allow the formation  
of a clear image for realizing an ideal point source  
10 (effective point source) by gathering the lamp energy  
efficiently.

The following will describe the full-size  
reflection-type exposing apparatus using the effective  
point source.

15 First, formation of an effective point source  
into an arc band by use of a 4th-degree surface reflector  
will be described. Figure 9 illustrates the optical  
system of the 4th-degree surface reflector. A line  
passing through the center of an arc band  $l_2$  and per-  
20 pendicular to a surface  $S_4$  of the arc band is defined  
as a revolving symmetric axis  $l$ , and an effective point  
source  $A_2$  is positioned on the axis. A 4th-degree surface  
is formed such that its profile  $\sigma$  (curve) obtained by  
cutting the surface on a plane  $S_3$  including the revolving  
25 symmetric axis forms an ellipse having one focal point  
located at the point source and another focal point  
at the intersection of the center line  $D$  of the arc  
band and the plane  $S_3$ . In such arrangement, it is

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1 clear due to the ellipsoidal profile  $\sigma$  that a ray  
emitted from the effective point source A2 and propagated  
on the plane S3 will reflect on the profile  $\sigma$  and will  
focus on the intersection I of the center line D and  
5 the plane S3. More generally, a ray emitted from point  
A2 and reflected on the surface  $\Sigma$  of the 4th-degree  
surface reflector will focus on arc D due to the fact  
that the surface  $\Sigma$  has its revolving symmetric axis on  
the line  $\ell$  and the center line D of the arc band has its  
10 revolving symmetric axis also on the line  $\ell$ . Although  
the effective point source A2 provides the luminous  
distribution extending around the arc band D due to a  
finite area of the light source, it illuminates the  
inside of the narrow arc band at a high light utilization  
15 efficiency owing to the high focusing characteristic at  
the point I.

Figure 9 shows the basic arrangement of the  
present invention, in which an effective point source 6  
is located at point A2 (focal point of ellipse  $\sigma$ ), and  
20 the 4th-degree surface is cut to form a reflector 32  
so that a ray projected to the center of the reflection  
surface  $\Sigma$  reflects in substantially perpendicular to the  
incident path. A diverging ray from the point source 6  
reflects on the surface  $\Sigma$  and focuses on the arc slit 12.  
25 Figure 10 is a ray tracing diagram for a ray emitted  
from the center, i.e., the focal point A2, of the diverg-  
ing effective point source 6 (indicated by the solid  
line) and a ray emitted from a point which is offset

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1 by  $\pm 0.5$  mm from the point A2 (indicated by the dot and  
dash line).

In contrast to the projecting ray shown in  
Fig. 10, Fig. 11A is a ray diagram on a plane perpendi-  
5 cular to the arc band when the 4th-degree surface having  
a ellipsoidal cross-section on the plane S3 is used  
according to the present invention. The solid line,  
dashed line, and dot and dash line in Fig. 10 corres-  
pond to those in Fig. 11. Figures 11B and 11C are ray  
10 diagrams of the conventional reflection-type optical  
system, Fig. 11B using a spherical mirror, Fig. 11C using  
the combination of three spherical mirrors. Figure 11A  
according to the present invention shows less failure  
of focusing as compared with any conventional case,  
15 and apparently a narrow area is illuminated effectively.

The following will describe the shape of the  
4th-degree surface mirror used in the embodiment of  
Fig. 9. If the arc band has a radius of curvature of  
 $r'$  (equal to A2 P), and if,

$$IP = mr'$$

20 then the 4th-degree surface  $\Sigma$ , with the origin located at  
point A2, is expressed as follows.

$$\begin{aligned} & \{ (2m+1)z^2 + m(m+2)(x^2+y^2) + 2m^2r'z - m^2r'^2 \}^2 \\ & = 4m^2(r'-z)^2(x^2+y^2) \dots\dots\dots (5) \end{aligned}$$

Figure 12 shows the full-size reflection-type

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1 exposing apparatus incorporating the foregoing embodiment of the present invention. A ray emitted from the effective point source 6 reflects on the 4th-degree surface 32 expressed by equation (5), and an arc slit  
5 illumination 12 is obtained on the mask 11. The ray transmitting the mask 11 reflects on the concave mirror 33 and convex mirror 34 twice and once, respectively, and projects an image pattern 36 of the arc slit on the wafer 35. Accordingly, by scanning the wafer  
10 35 and the mask 11 at the same speed in respective directions shown by the arrows, the pattern of the mask 11 can be exposed on the entire surface of the wafer 35.

Figure 13 shows an embodiment of the full-size reflection-type exposing apparatus according to the  
15 present invention, in which reference number 4 denotes a point source employing a Xe-Hg lamp, and 30 and 31 are concave mirrors for converging the light emitted from the point source. In this embodiment, the following concave mirrors are used for the mirrors 20 and 21  
20 shown in Fig. 4.

(1) The concave mirror 30 is derived from the 4th-degree surface mirror 20 defined by equation (5) with  $m = m_1$ .

(2) The concave mirror 31 is derived from the 4th-degree surface mirror 21 defined by the equation (5)  
25 with  $m = m_2$ .

The spatial relationship between the concave mirrors 20 and 21 is that they have a common revolving

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1 symmetric axis and their focal points, which are the  
intersections of a plane including the revolving symmetric  
axis and the reflection surfaces of both concave mirrors  
and are located out of the revolving symmetric axis,  
5 are located substantially at the same point. In this  
arrangement, the 4th-degree surface mirrors 20 and 21  
provide an effective point source at point 6. Using  
this effective point source as a new point source, an  
arc band illumination 12 can be obtained by use of a  
10 4th-degree surface 2 in the same way as in the embodi-  
ment shown in Fig. 9. Figure 14 is a ray diagram for  
the illumination system formed by the combination of  
three 4th-degree surfaces each having an ellipsoidal  
cross-section, showing the characteristics of a ray  
15 emitted from the center A1 of the light source 4 in the  
arrangement of Fig. 13 (indicated by the solid line) and  
rays emitted from the points which are offset by  $\pm 0.5$  mm  
from the center (indicated by the dashed line, and dot  
and dash line) on the mask 11 shown in Fig. 13. The  
20 figure shows that a better arc band illumination can be  
obtained as compared with the cases of Figs. 11B and  
11C.

Next, another embodiment will be described in  
connection with Fig. 13. In this embodiment, concave  
25 mirrors 30 and 31 are of the type shown by 24 and 25 in  
Fig. 6.

(3) Concave mirror 31: Identical to mirror 25

As shown in Fig. 15, the concave mirror 25 has

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1 a revolving symmetric axis  $\ell_{21}$  passing through a light  
 source 4, and the intersection of a plane  $S_{21}$  ( $x/z$  plane)  
 including the symmetric axis and the concave mirror 25  
 defines a circle with its center located out of the ray  
 5 axis  $\ell_{21}$ . When the light source is located on the  
 origin, the center of the circle is located at  $(x_0, z_0)$ ,  
 and the surface  $\Sigma$  of the concave mirror 25 satisfies the  
 following 4th-degree equation.

$$\{r_c^2 - (z - z_0)^2 - x^2 - y^2 - x_0^2\}^2 - 4x_0^2(x^2 + y^2) = 0 \dots (6)$$

(4) Concave mirror 30: Identical to mirror 24

10 The concave mirror 30 is identical to that shown  
 in Fig. 15 and has the same revolving symmetric axis.  
 The location of point  $0''$  corresponding to point  $0'$  of  
 the mirror 25 is defined, for example, as  $0' - 0'' = 81$  mm  
 when  $r_c = 250$  mm,  $x_0 = 75$  mm and  $z_0 = 177$  mm.

15 The ray diagram on the mask surface 4 according  
 to this embodiment is shown in Fig. 16 (the illumination  
 ray by the illumination system formed by the combination  
 of two 4th-degree surface each having a circular cross-  
 section and a 4th-degree surface having an ellipsoidal  
 20 cross-section). The figure shows that the similar or  
 better arc band illumination is obtained as compared  
 with the case of Fig. 14. It will be appreciated that  
 light emitted from the point source 4 and traveling in  
 directions opposite to the concave mirror 31 can be used  
 25 effectively by provision of a spherical mirror 13 having



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1 its center of curvature located at the point source.

Next, still another embodiment will be described in connection with Fig. 13 and Fig. 5. The light emitted from the lamp 4, used as a point source, is  
5 converged to form an arc band shown by the dashed line in Fig. 5 using a 4th-degree surface mirror having its revolving symmetric axis formed by the line 7 shown in the embodiment of Fig. 1 and also having an ellipsoidal cross-section. If a 4th-degree concave mirror 22,  
10 having a hyperbolic cross-section with its focal points located on the arc and having the revolving symmetric axis 7, is inserted between the ellipsoidal concave mirror and the arc, the light emitted from the light source 4 will converges to form an effective point  
15 source at point 6.

In converging the point source originated from the lamp to form an effective point source by using the foregoing reflection-type optical system, if a pinhole filter 9 having a circular opening (pinhole) is placed  
20 at the focal point as shown in Fig. 13, the area of the light source can be made smaller so that it further approaches the real point source. The optical systems as shown in Figs. 3, 4A and 5A can be replaced by a simple and ideal point light source.

25 The full-size reflection-type exposing apparatus using the reflection-type optical focusing apparatus according to the present invention will be described with reference to Fig. 17. Reference number 40 denotes

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1 the reflection-type optical focusing apparatus shown in  
Fig. 13, and it is mounted on a flat plate 41. In  
order to take a longer distance between the concave  
mirrors 30 and 31, the apparatus is provided with flat  
5 reflectors 36 and 37. A moving tray 42 is supported  
slidably by a bearing 47 on the flat plate 41. A means  
43 for holding a mask 11 is fixed on the moving tray 42.  
An X-Y-θ table 44 for mounting a wafer 35 is fixed on  
the moving tray 42. Reference number 45 denotes a  
10 driving power source for moving the tray 42, and its  
output is connected through a steel belt or the like 46  
to the moving tray 42. A full-size reflection-type  
optical system 50 includes reflectors 51, 52 and 53,  
a concave spherical mirror 33 and a convex spherical  
15 mirror 34, and it is mounted on a support 48 provided on  
the flat plate 41. Reference number 54 denotes an  
optical detection system for registering the alignment  
pattern on the wafer 11 to the alignment pattern on the  
mask 35. In the foregoing arrangement, the wafer 35  
20 and the mask 11 are aligned by using the optical  
detection system 54, thereafter circuit patterns projected  
in the form of an arc band on the mask 35 by the reflection-  
type focusing apparatus 40 is transferred onto the wafer  
11 by moving the tray 42 in a certain direction.

25 The reflection-type optical focusing apparatus  
according to the present invention can be used not only  
for the above-mentioned full-size reflection-type exposing  
apparatus, but more extensively for exposing apparatus

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1 of the type where exposure is carried out by scanning  
the mask and wafer. For example, application of the  
apparatus to a contact exposing apparatus and proximity  
exposing apparatus using ultraviolet rays or deep  
5 ultraviolet rays provides the following advanced characteristics as compared with the conventional system. It  
has been impossible to obtain a uniform and parallel  
illumination ray from a point source solely by using  
a reflection-type optical system, and therefore, fly-eye  
10 lens made of transmitting quartz and quartz lens have  
been used. However, such optical system using expensive  
quartz components has not provided a satisfactory uniform  
and parallel illumination ray. The illumination  
apparatus for exposing apparatus according to the present  
15 invention achieves a constant luminous level in any  
place on the arc band and also a satisfactory parallel  
ray. Moreover, the illumination apparatus for exposing  
apparatus according to the present invention does not  
need transmitting optical components (by choosing the  
20 value of  $m$  in the range from 2 to 5), thereby allowing  
the low-cost design. This advantage is further stressed  
for the light having a shorter wave length for which  
transmitting optical components cannot be used.

According to the present invention, as described  
25 above by way of embodiment, the light emitted from a  
point source or a light source having a small lighting  
area similar to the point source can be projected to a  
narrow area in the form of an arc band clearly, whereby

- 1 only the narrow arc band pattern can be exposed onto the wafer. Therefore, only the satisfactory narrow arc band area produced by the optical projection system made up basically of concave and convex mirrors is used to
- 5 expose the wafer by scanning the mask and wafer at a high speed, and a high resolution pattern can be transferred to the wafer at a high speed.

Thus the present invention is very effective for improving the quality of focusing and economical

10 condition at the same time.

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## 1 WHAT IS CLAIMED IS:

1. A reflection-type optical focusing apparatus comprising a 4th-degree surface reflector (32) with its cross-section, on a plane including a revolving symmetric  
5 axis, forming a part of an ellipse with its major axis having a certain inclination with respect to said revolving symmetric axis, a virtual point source being located at one focal point (A2) of said ellipse so that a light image in the shape of an arc band (12) is  
10 produced.

2. A reflection-type optical focusing apparatus according to Claim 1, wherein at least two 4th-degree surface reflectors (20, 21; 22, 23; 24, 25) having their revolving symmetric axis formed by a line (7)  
15 connecting the position of a point source (A1) and the point source focusing position (A2), said reflectors being used in combination such that the light emitted from a point source located at said point source position is focused to form a point source at said point  
20 source focusing position.

3. A reflection-type optical focusing apparatus according to claim 2, wherein said two 4th-degree surface reflectors have their conjugate points located at said point source position (A1) and said point source  
25 focusing position (A2), said reflectors comprising a first 4th-degree surface reflector (21) with its cross-section, on a plane including said revolving symmetric axis, forming a part of an ellipse having its focal

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points located at one (A1) of said conjugate points and a point (C) out of said revolving symmetric axis, and a second 4th-degree surface reflector (20) with its cross-section, on a plane including said revolving symmetric axis, forming a part of an ellipse having its focal points located at a point (C) out of said revolving symmetric axis and another one (A2) of said conjugate points.

4. A reflection-type optical focusing apparatus according to claim 2, wherein said two 4th-degree surface reflectors have their conjugate points located at said point source position (A1) and said point source focusing position (A2), said reflectors comprising a first 4th-degree surface reflector (23) with its cross-section, on a plane including said revolving symmetric axis, forming a part of an ellipse having its focal points located at one (A1) of said conjugate point and a point (C) out of said revolving symmetric axis, and a second 4th-degree surface reflector (22) with its cross-section, on a plane including said revolving symmetric axis, forming a part of a hyperbola having its focal points located at a position (C) out of said revolving symmetric axis and another one (A2) of said conjugate points.

5. A reflection-type optical focusing apparatus according to claim 2, wherein said two 4th-degree surface reflectors (24, 25) have their conjugate points located at said point source position (A1) and said point source focusing position (A2), each of said

- 3 -

reflectors having its cross-section, on a plane including said revolving symmetric axis, forming a part of a circle with its center of curvature located out of said revolving symmetric axis.

5 6. A reflection-type optical focusing apparatus according to claim 2, wherein a small circular aperture is provided at the position (A2) of said virtual point source.

7. A reflector-type optical focusing apparatus  
10 for use in an exposing apparatus which focuses a light image illuminated on a mask in the shape of an arc band onto a wafer (35) by means of an optical focusing system, said focusing apparatus comprising an optical focusing system including at least two 4th-degree surface reflectors (30, 31) with their revolving symmetric axis  
15 formed by a line connecting the position of a point source (A1) and the point source focusing position (A2), said reflectors being used in combination so that the light emitted from a point source placed at said point  
20 source position is focused to form a virtual point source at said point source focusing position, and a 4th-degree surface reflector (32) with its cross-section, on a plane including said revolving symmetric axis, forming a part of an ellipse with its major axis having  
25 a certain inclination with respect to said revolving symmetric axis, said virtual point source being located at one focal point (A2) of said ellipse so that said light image in the shape of an arc band (12) is obtained.

- 4 -

8. A reflection-type optical focusing apparatus  
for use in an exposing apparatus according to claim 7,  
wherein said optical focusing system in said exposing  
apparatus comprises a full-size reflection-type optical  
5 system including a concave spherical mirror (33) and a  
convex spherical mirror (34).



FIG. 1

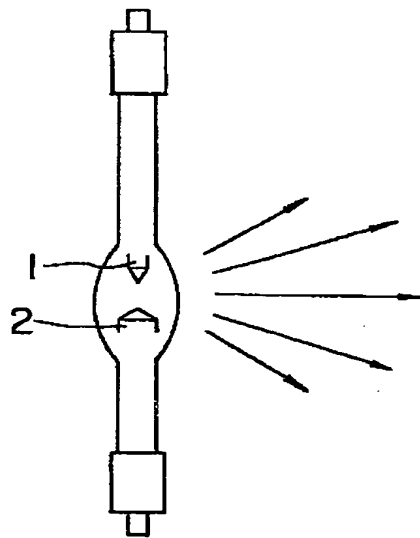


FIG. 3

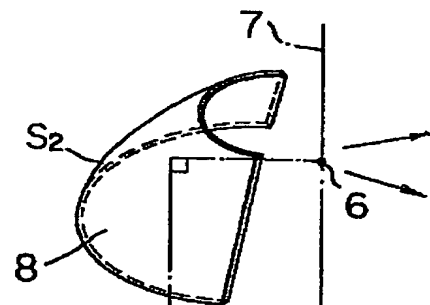


FIG. 2A  
PRIOR ART

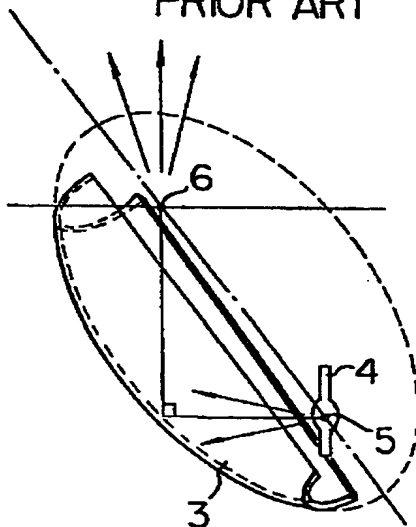


FIG. 2B  
PRIOR ART

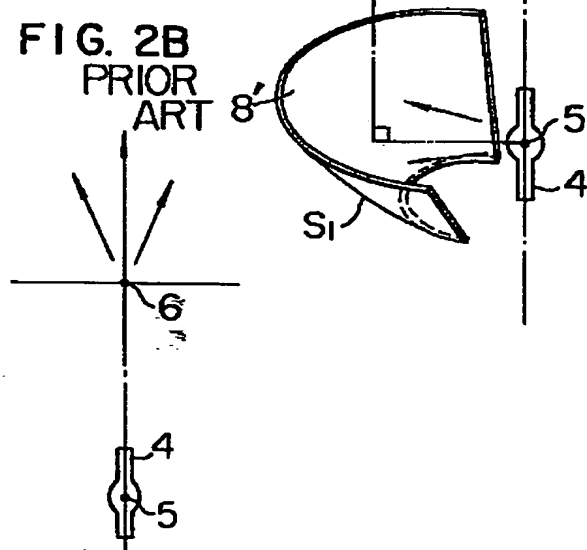


FIG. 4A

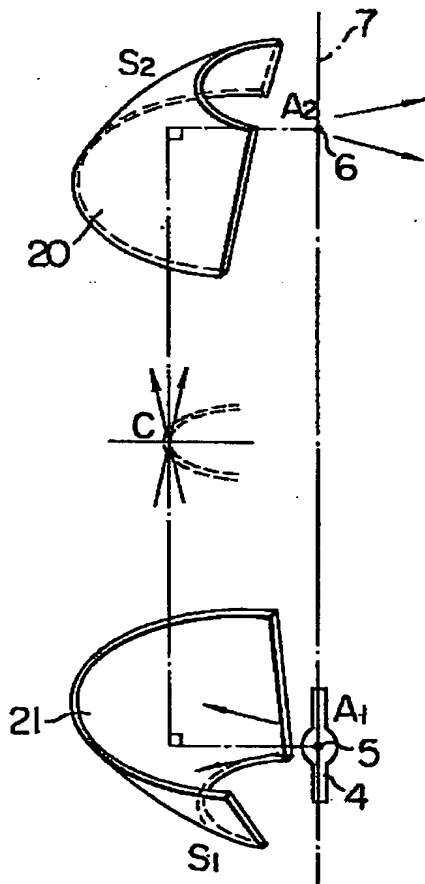


FIG. 4B

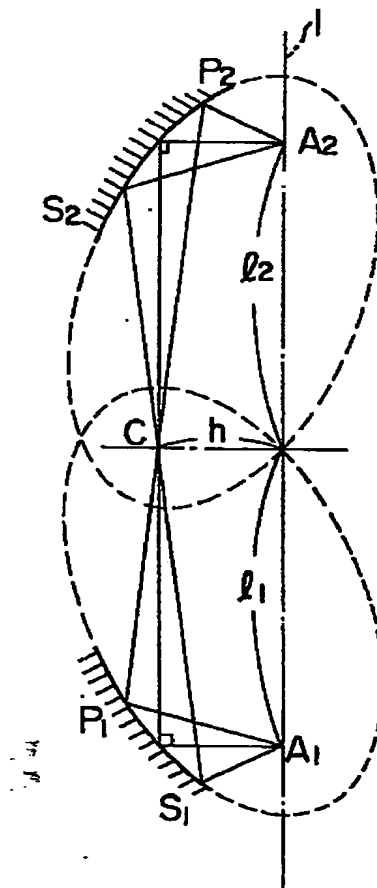


FIG. 5B

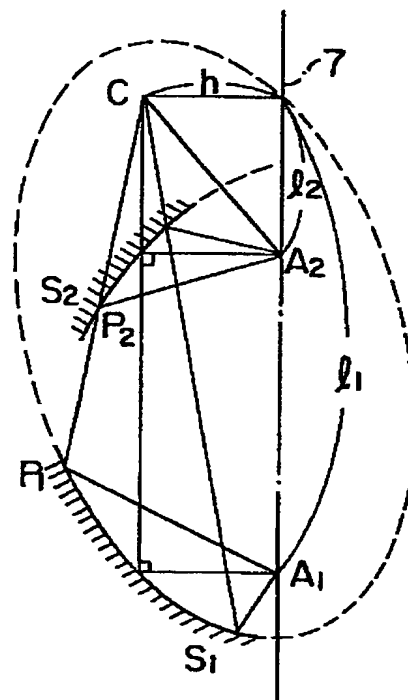
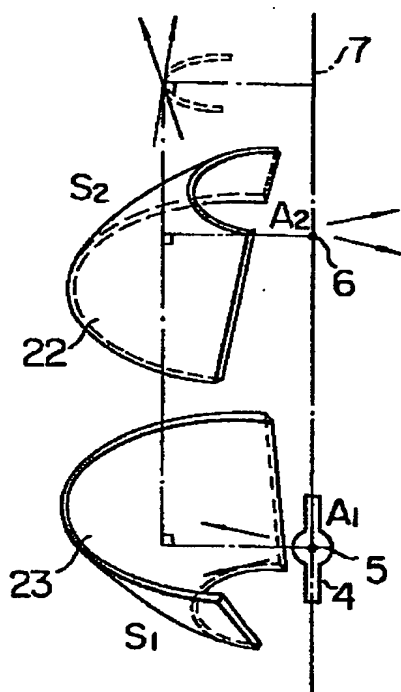
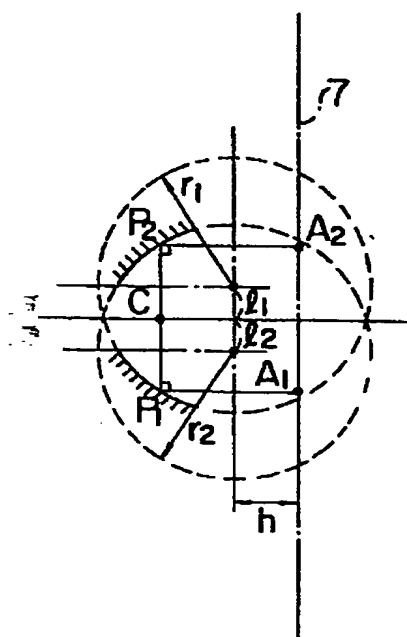
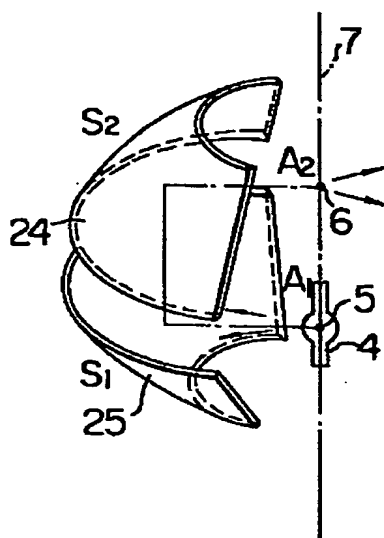


FIG. 6B



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FIG. 7A

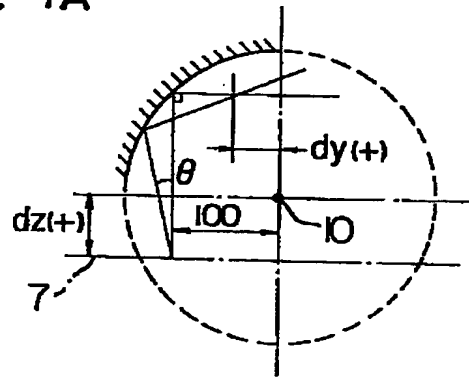
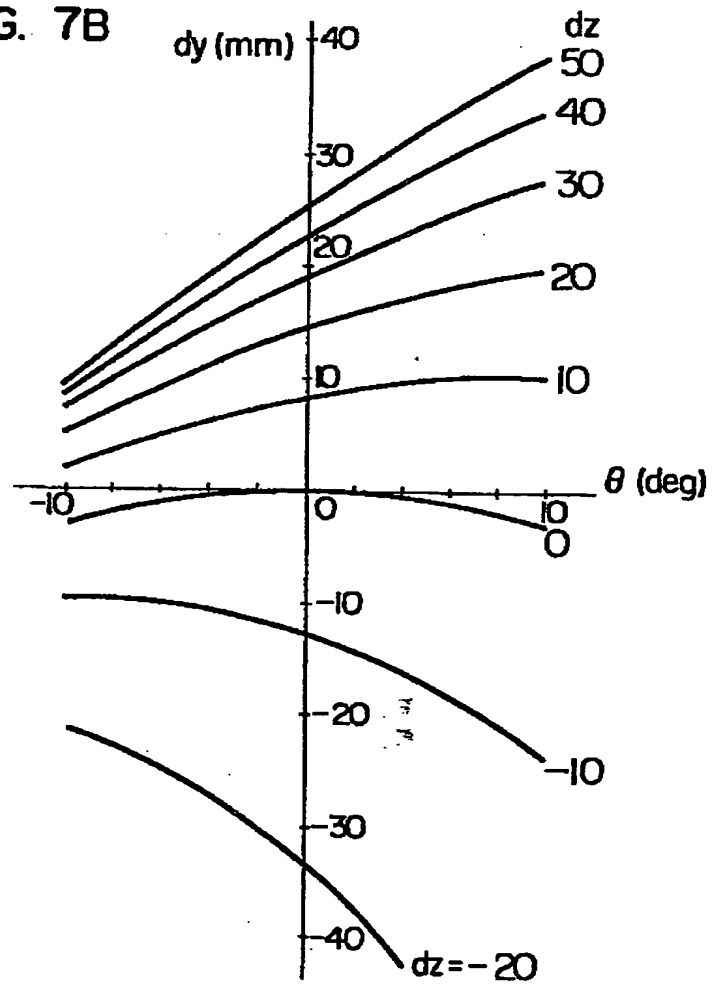
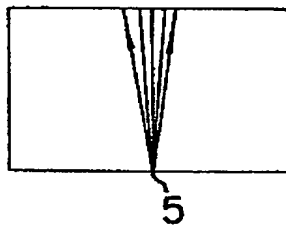


FIG. 7B



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FIG. 8A



1 mm

FIG. 8B

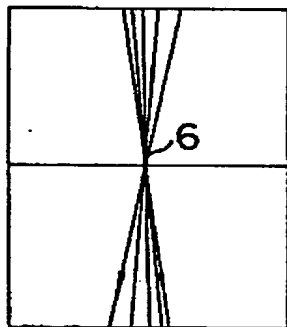


FIG. 8D

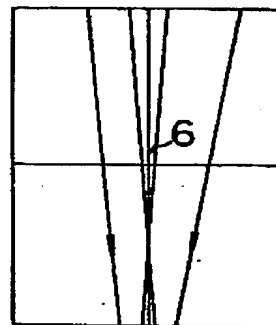


FIG. 8C

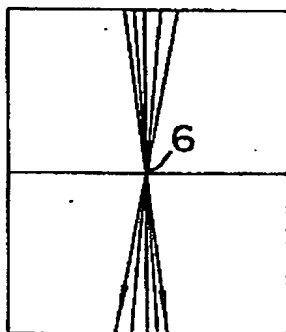
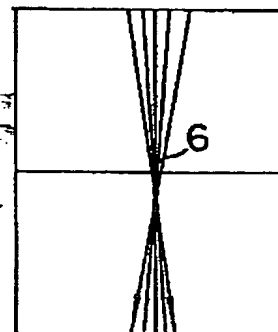


FIG. 8E



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FIG. 9

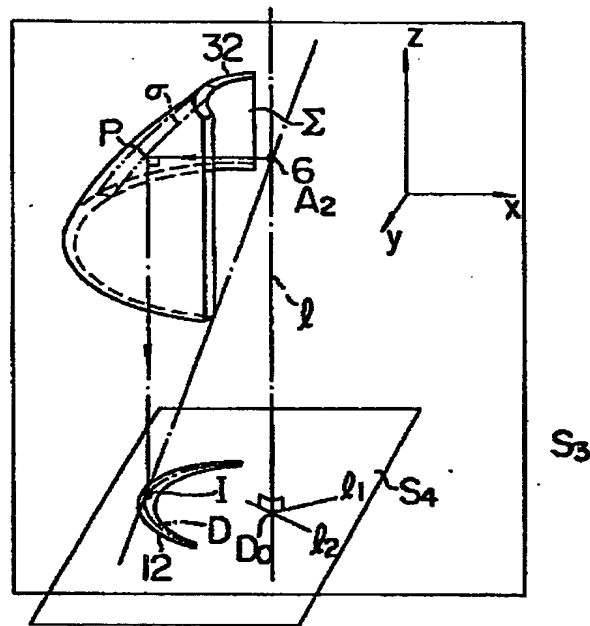
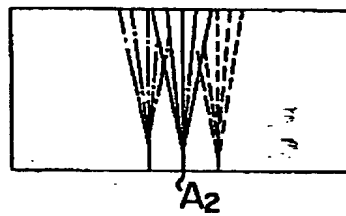
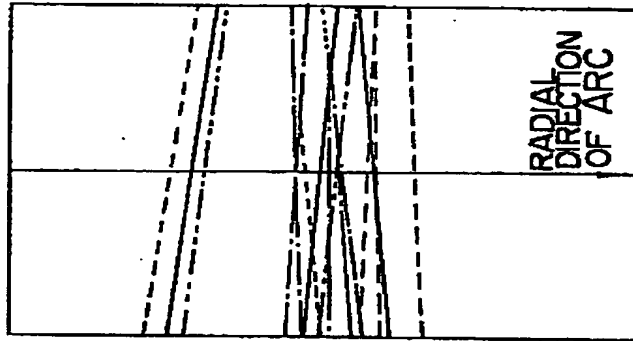


FIG. 10



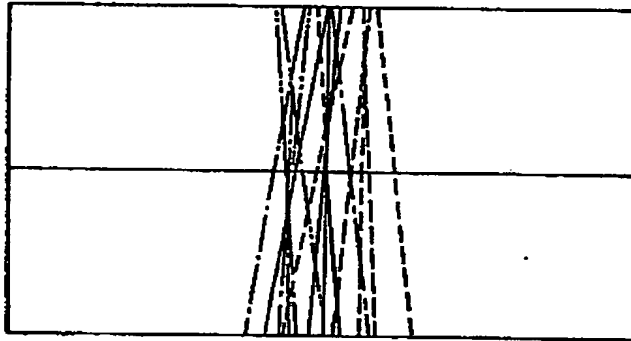
0 1 2mm

FIG. IIC



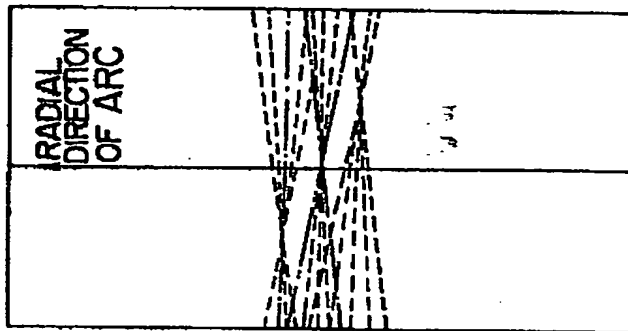
0 1 2mm

FIG. IIB



0 1 2mm

FIG. IIA



0 1 2mm

FIG. 12

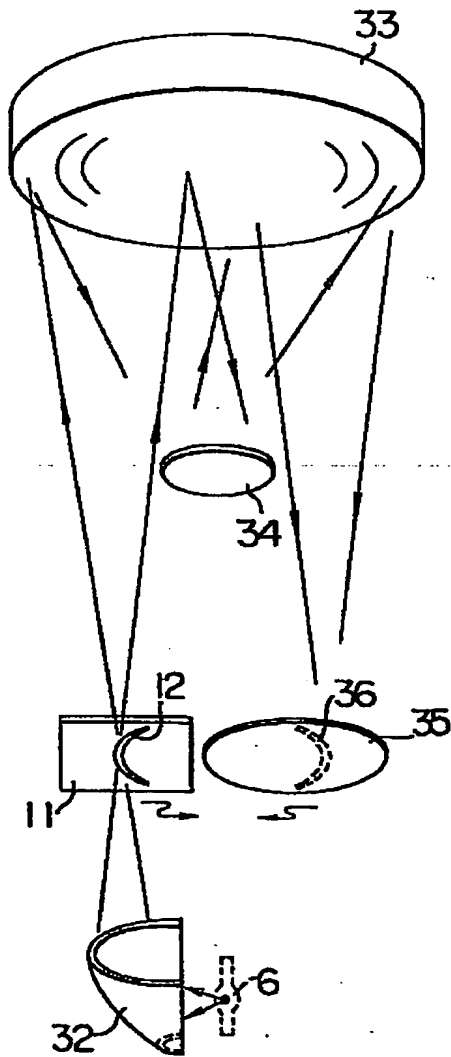
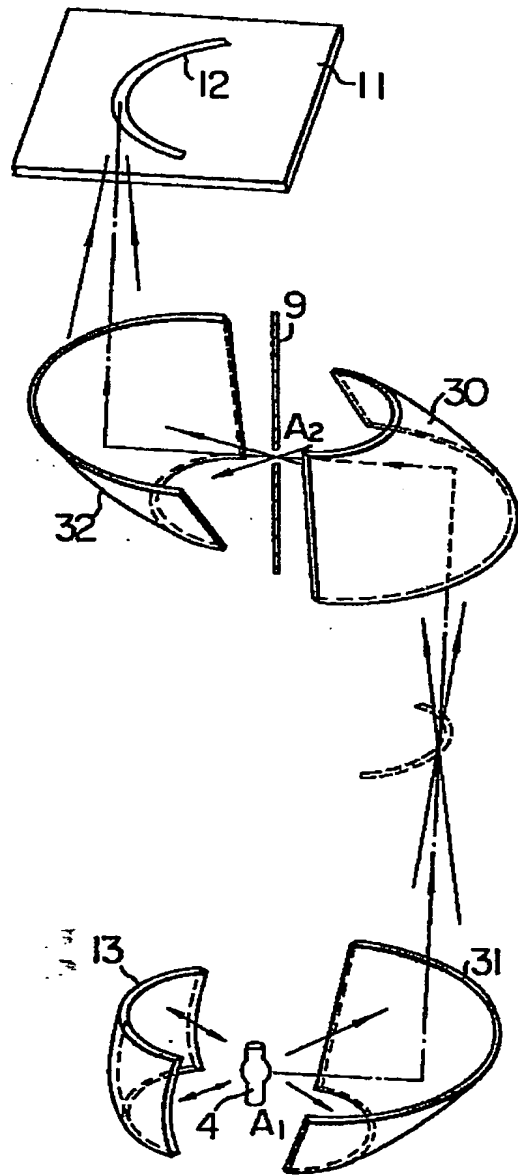


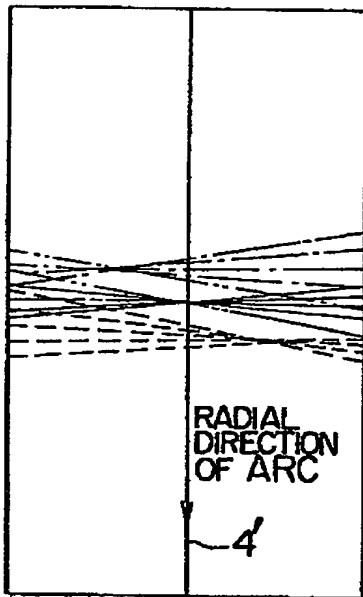
FIG. 13





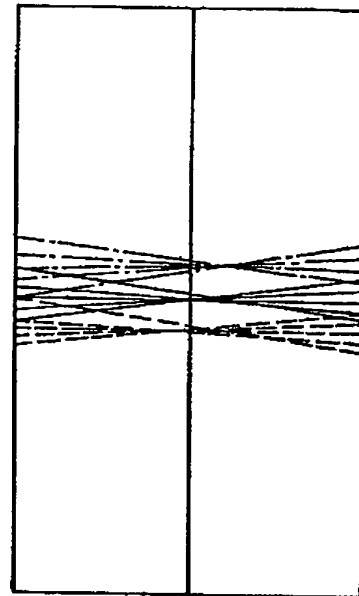
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FIG. 14



0 1 2mm

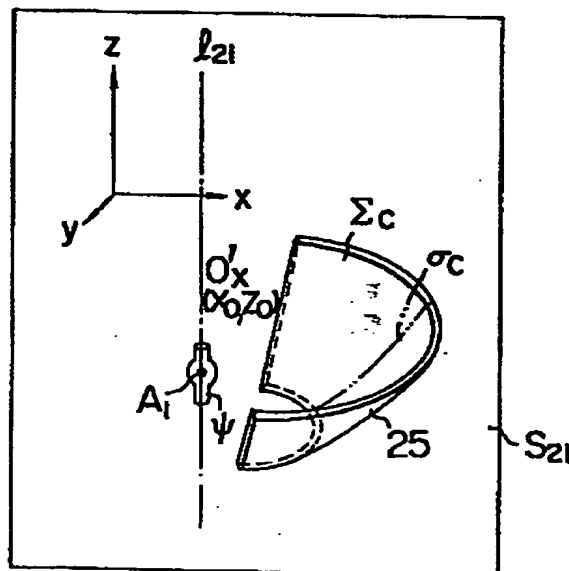
FIG. 16



SPHERE/SPHERE  
/ELLIPSE  
(MODIFICATION  
SYSTEM) THE 3RD  
REFLECTION

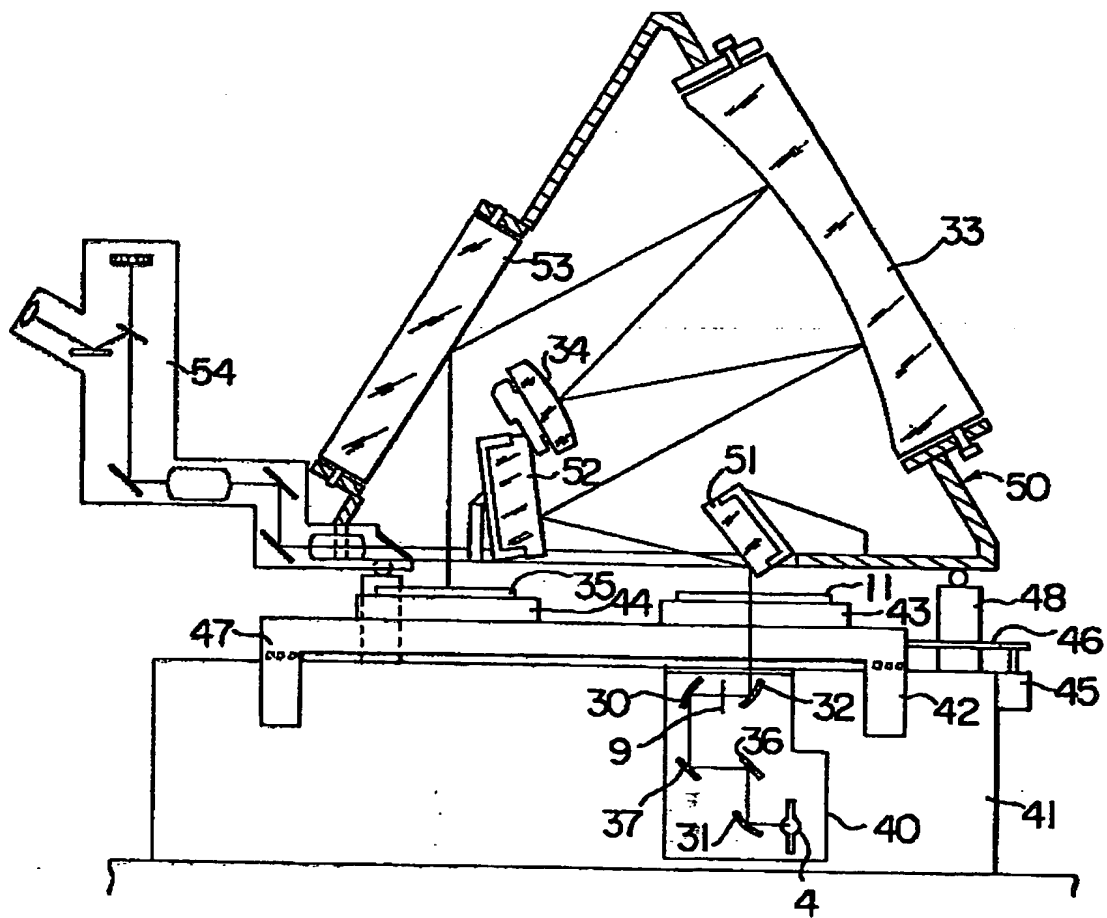
0 1 2mm

FIG. 15



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FIG. 17





Eur pean Pat nt  
Office

# EUROPEAN SEARCH REPORT

0066295

Application number

EP 82 10 4828

| DOCUMENTS CONSIDERED TO BE RELEVANT   |  |  |  |
|---|--|--|--|
| Category  | Citation of document with indication, where appropriate, of relevant passages  | Relevant to claim  | CLASSIFICATION OF THE APPLICATION (Int. Cl. 3) |
| Y   | DE-A-2 910 280 (CANON)<br><br>*Page 5, lines 21-35; page 8, lines 6-16; claims 1-3; figures 2,6* & US - A - 4 294 538 (Cat. D,P,Y) | 1-5,7,8  | G 02 B 17/00<br>G 02 B 19/00                   |
| Y   | EP-A-0 022 346 (EALING INFRA-RED)<br>*Page 3, lines 1-13; figure 3; claims 1-6*  | 1-5  |  |
| A   | DE-A-2 505 257 (RICOH CO.)<br>*Abstract; figures 7,8*  | 1,7  |  |
| A   | US-A-3 763 348 (COSTELLO)<br>*Abstract; figure 4*  | 1,7  |  |
| A   | US-A-3 963 353 (HEMSTREET)<br>*Column 2, lines 3-5,22-28; figure 1*  | 1,7  |  |
|   |  |  | TECHNICAL FIELDS SEARCHED (Int. Cl. 7)         |
|   |  |  | G 02 B<br>G 03 B                               |
| The present search report has been drawn up for all claims  |  |  |  |
| Place of search<br>THE HAGUE  |  | Date of completion of the search<br>21-07-1982   | Examiner<br>SEIFERT H.U.                       |
| CATEGORY OF CITED DOCUMENTS   |  |  |  |
| X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |  | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br><br>& : member of the same patent family, corresponding document |  |